~~AP01-257 (K. Ebata/I. Kusatsu)~~

TITLE OF THE INVENTION

X DOWNSIZE, HIGH PERFORMANCE, AND WIDE RANGE MAGNIFICATION ZOOM LENS AND CAMERA APPARATUS

~~CROSS REFERRENCE TO A RELATED APPLICATION~~

This application claims priority under 35 USC §119 to Japanese Patent Application Nos. 2000-352498 filed on November 20, 2000, and 2001-037445 filed on February 14, 2001, the entire contents of which are herein incorporated by reference.

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BACKGROUND OF THE INVENTION

Field of the Invention

The present invention generally relates to zoom lenses and camera apparatuses, in particular to zoom lenses and camera apparatuses that are downsized and capable of exerting a high performance and a wide range magnification.

Discussion of the Background

In these later days, it becomes the nature of things that a digital camera that is rapidly spreading has a zooming function of a photographing lens. Accordingly, high image quality, wide range magnification, downsizing, and electrical power saving are sought in order to accommodate a photo-

acceptance unit having a high density such as more than three million pixels. (whole application)

Japanese Patent Application Laid Open Nos. 06-180424, 07-151967, and 09-090221 or the like propose the below described technology that is suitable for enabling a zoom lens for use in a digital camera to have a high performance and wide range magnification. Specifically, the first lens band having a positive focal length, the second lens band having a negative focal length, and the third, fourth and fifth lens bands having positive focal lengths are arranged in this order from an object side. In addition, magnification from short to long focal point ends is performed by smoothly moving the second lens band from the object side toward an image surface. Also, an image surface positional variance that accompanies such magnification is compensated by moving the fourth lens band.

However, in any one of zoom lenses described in these official gazettes, the fourth lens band moves in order to compensate the positional variance of an image surface, which accompanies the magnification, and rarely contributes to the magnification. Specifically, the second lens band substantially bears all of the magnifying function.
As a result, a moving amount of the second lens band that accompanies the magnification is large, and the first lens

share (whole application)

long focal point end so as to ~~shear~~ a magnification function together with the second lens band.

In another embodiment, a distance D_{1W} between the first and second lens bands at the short focal point end, a distance D_{1T} between the first and second lens bands at the long focal point end, a distance D_{3W} between the third and fourth lens bands at the short focal point end, and a distance D_{3T} between the third and fourth lens bands at the long focal point end substantially meet the following inequality:

$$(D_{3W} - D_{3T}) \ / \ (D_{1T} - D_{1W}) > 0.3$$

In yet another embodiment, the zoom lens may be photograph use and the first lens band may be nearest to an object to be photographed.

In yet another embodiment, the fourth lens band May come closest to the third lens band at a focal length slightly before the long focal point end.

In yet another embodiment, a positional variance of an image surface, which is caused by these smooth movements of the second and fourth lens bands, may be compensated by movement of the fifth lens band.

In yet another embodiment, the first lens band is immobile.

In yet another embodiment, the third lens band and the aperture diaphragm are immobile.

length;

Fig. 15 is a schematic chart for illustrating a set of aberration curvatures of the third exemplary zoom lens at a long focal length;

Fig. 16 is diagram for illustrating a set of aberration curvatures of the fourth exemplary zoom lens at a short focal point end;

Fig. 17 is a diagram for illustrating a set of aberration curvatures of the fourth exemplary zoom lens at a middle focal length;

Fig. 18 is a schematic chart for illustrating a set of aberration curvatures of the fourth exemplary zoom lens at a long focal length;

Fig. 19 is diagram for illustrating a set of aberration curvatures of the fifth exemplary zoom lens at a short focal point end;

Fig. 20 is a diagram for illustrating a set of aberration curvatures of the fifth exemplary zoom lens at a middle focal length;

Fig. 21 is a schematic chart for illustrating aberration curvature of the fifth exemplary zoom lens at a long focal length;

Fig. 22 is a schematic chart for illustrating one example of a camera apparatus;

Figs. 23A, 23B and ~~23C~~ are schematic charts for

illustrating lens arrangement during magnification and in a macro mode of sixth example;

Figs. 24A 24B and ~~24C~~ are schematic charts for illustrating lens arrangement during magnification and in a macro mode of the seventh example;

Fig. 25A 25B and ~~25C~~ are schematic charts for illustrating lens arrangements during magnification and in a macro mode of the eighth example;

Fig. 26 is a schematic chart for illustrating a set of aberration curvatures of the sixth example at a short focal point end when a photographing distance is infinity;

Fig. 27 is a schematic chart for illustrating a set of aberration curvatures of the sixth example at a middle focal length when a photographing distance is infinity;

Fig. 28 is a schematic chart for illustrating a set of aberration curvatures of the sixth embodiment in a long focal point end when a photographing distance is infinity;

Fig. 29 is a schematic chart for illustrating a set of aberration curvatures of the sixth example at the short focal point end when a photographing distance is 0.3 millimeter; s (whole application)

Fig. 30 is a schematic chart for illustrating a set of aberration curvatures of the sixth example at the middle focal length when a photographing distance is 0.4 millimeter

Fig. 31 is a schematic chart for illustrating a set of

aberration curvatures of the eighth example at the long focal point end when a photographing distance is 0.5 millimeter;

Fig. 48 is a schematic chart for illustrating a set of aberration curvatures of the eighth example in a macro mode when a photographing distance is 0.3 millimeter; ~~and~~

Fig. 49 is a schematic chart for illustrating a set of aberration curvatures of the eighth example in the macro mode when a photographing distance is 0.77 millimeter; and

Figs. 50 through 57 include tables for illustrated examples of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout several views, and in particular in Figs. 1A and 1B, a zoom lens may include the first lens band having a positive focal length, the second lens band having a negative focal length, and the third to fifth lens bands having the positive focal lengths. Also included may be an aperture diaphragm disposed in the vicinity of the third lens band. When magnification from short to long focal point ends is performed, the second lens band may smoothly move toward the third lens band. Simultaneously, the fourth lens band may move from the fifth lens band toward a long focal point end in the vicinity of the third lens band. Thereby, the fourth lens band may shear a magnifying function together with the second lens band.

at a short focal point end, the reference numeral D_{1T} represents a distance between the first and second lens bands at a long focal point end, the reference numeral D_{3W} represents a distance between the third and fourth lens bands at a short focal point end, and the reference numeral D_{3T} represents a distance between the third and fourth lens bands at a long focal point end:

$$(D_{3W}-D_{3T}) \ / \ (D_{1T}-D_{1W}) > 0.3$$

The above-described formula may represent necessity of increase in a moving amount of the fourth lens band more than a prescribed level when magnification is performed. Specifically, if the parameter $(D_{3W}-D_{3T})/(D_{1T}-D_{1W})$ becomes smaller than the lower limit 0.3, there may be a pro~~x~~bability that the fourth lens band does not sufficiently shear the magnifying function. For example, if supposing a case in which the third lens band is fixed, the element $(D_{3W}-D_{3T})$ may indicate a moving amount of the fourth lens band when magnification from the short to long focal point ends is performed. Similarly, the denominator $(D_{1T}-D_{1W})$ may indicate a moving amount of the second lens band when magnification is performed.

Thus, minimization of the parameter $(D_{3W}-D_{3T}) \ / \ (D_{1T}-D_{1W})$ may denote minimization of the element or enlargement of the denominator. The minimization of the element may denote decrease in a moving amount of the fourth lens band. In contrast, enlargement of the denominator may denote enlargement of a

moving amount of the second lens band. Accordingly, a magnifying function to be sheared by the fourth lens band may be minimized in any cases.

Further, along as becomes larger, a rate of shearing magnifying function by the fourth lens band may become larger. However, if the magnifying function shear rate by the fourth lens band becomes excessively large, the magnifying function shear rate of the second lens band may become smaller, thereby resulting in difficulty in obtaining fair magnification. Accordingly, a limit of the parameter $(D_{3W}-D_{3T}) / (D_{1T}-D_{1W})$ may be around 1.0.

The above-described zoom lens may be novel to the extent that the fourth lens band shears a magnifying function together with the second lens band.

It can be utilized as a projector use zoom lens in a liquid crystal projector.

In addition, the zoom lens can be a photographic ~~use~~ zoom lens whose first lens band is arranged in an object side.

In addition, as illustrated in Fig. 1A, the fourth lens band may come closest to the third lens band during its movement from the fifth lens band side toward the long focal point end in the vicinity of the third lens band for magnification at a focal point slightly before the long focal point end.

Further, the zoom lens can have both of functions of

magnifying and compensating an image surface positional variance that accompanies the magnification at once.

Specifically, as illustrated in Fig. 1B, when magnification from the short to long focal point ends is performed, the fourth lens band smoothly moves from the fifth lens band side toward the long focal point end in the vicinity of the third lens band.

The positional variance of an image surface may accompany the magnification performed by the smooth movement of the second and fourth lens bands. The positional variance may be compensated by a movement of the fifth lens band.

If compensating the image surface variance, flexibility of improvement in a performance may increase and a higher performance may readily be obtained. In addition, since smooth movement is performed by each of the second and fourth lens bands in such a manner, a mechanism for use in a lens band movement may be simplified and accomplished with a lower torque.

In one example of zoom lens, the first lens band can be fixed. Such fixation may represent a stable, permanently ~~an all the time~~ fixed condition ~~and being stable~~. To achieve the lens band movement with a simpler mechanism, the first lens band may preferably always be fixed. Because, the first lens band is biggest and heaviest, movement of the first lens band may be easy to impair simplicity of the mechanism and electrical power saving. In

addition, when movement of the first lens band performs focussing, the first lens band may become large owing to reservation of a circumference light quantity at a close range.

In another example of a zoom lens, the third lens band and an aperture diaphragm may be fixed. Because, a shutter (not shown) is sometimes arranged at a position of the aperture diaphragm, and displacement of the shutter may unfortunately cause a mechanism to be complex. If a shutter movable configuration is employed, vibration generated when the shutter is driven may easily travel to another portion of a lens unit, and is a possible cause of image vibration.

In another exemplary zoom lens, focussing can be performed by integrally moving the whole lens units. In a case of imaging on a light-receiving surface of a photo-acceptance unit such as a CCD or the like, the photo-acceptance unit can be moved.

Otherwise, inner focussing performed by moving one or more lens bands other than the first lens band may be employable.

In any way, focussing can be performed by movement of the fifth lens band.

When performing the inner focussing, the fifth lens band is most preferably utilized for focussing.

The ~~A~~ ~~moving~~ amount of movement required to adjust a focal point of an object of a prescribed distance may be smaller at the short focal

point end, and larger at the long focal point end, in contrast. However, since an interval between the fourth and fifth lens bands may be small when lens band moves to the short focal point end, and large when they moves to the long focal point end as similar to the above, movement of the fifth lens band for focussing may not be impaired by the fourth lens band.

In addition, if a positional variance of an image surface which accompanies magnification is compensated by movement of the fifth lens band, an advantage that a moving mechanism and a control device for focussing and compensating an image surface can be designed in common may be obtained.

In one example of a zoom lens, the following inequality may be preferably met by the focal length f_1 of the first lens band and the composite focal length f_{12T} of the first and second lens bands in order to further downsize and obtain a higher performance:

$$-1.4 < (f_{12T} / f_1) < -1.0$$

Such parameter (f_{12T}/f_1) may denote a magnification rate of the second lens band at the long focal point end. To downsize a lens unit, power of the first lens band is required to be strengthen (i.e., to shorten a focal length). To achieve such a ~~In order to~~ design the ~~in such a manner, it may be preferable that a~~ magnification rate of the second lens band at the long focal point end preferably may be set at less than -1. On the other hand, if the magnification rate

owned by the second lens band at the long focal point end is less than -1.4, since contribution of the fourth lens band to the magnification is weakened and the power of the second lens band should be strengthened, disadvantage may arise in aberration compensation.

Thus, one example of zoom lens may preferably substantially meet the following inequality, wherein the reference numeral f_{12W} represents the composite focal length of the first and second lens bands at the short focal point end, the reference numeral f_{12T} represents the composite focal length of the first and second lens bands at the long focal point end, and the reference numeral f_{1T} represents a focal length of the whole lens units at the long focal point end, and the reference numeral f_{1W} represents a focal length of the whole lens units at the short focal point end:

$$0.4 < (f_{12T} / f_{12W}) / (f_T / f_W) < 0.7$$

The element (f_{12T}/f_{12W}) may indicate a magnification change of the second lens band.

The denominator (f_T/f_W) may indicate a magnification rate of a zoom lens as it is. If the parameter $(f_{12T}/f_{12W})/(f_T/f_W)$ exceeds the upper limit 0.7, a magnifying function of the fourth lens band is insufficient, and the first lens band may generally be increased in size (whole application) ~~jumboized~~. In contrast, when the parameter $(f_{12T}/f_{12W})/(f_T/f_W)$ lowers the lower limit 0.4, the magnifying function of the second

lens band may excessively become weak and a change in an incident pupil radius at the time of zooming may become small. As a result, a variance of the F-number from the short to long focal point ends may unavoidably become large when a diameter of an aperture diaphragm is set constant.

If the variance of the F-number is large, either minimization of the F-number at the short focal point end or enlargement of the F-number at the long focal point end should optionally be selected. However, if the F-number of the short focal point is minimized, aberration is hardly compensated. In contrast, when the F-number of the long focal point is enlarged, it may be easy to receive affection of hand shaking or the like. In addition, a method for maintaining the F-number constant by varying the aperture diaphragm diameter at the time of zooming can be employed. However, it is not preferable because a mechanism (i.e., a shutter) for the diaphragm becomes complex.

In the above-described zoom lens, less than three lenses may constitute each lens band. More than one non-spherical surface~~s~~ may be employed in each of the second and third lens bands. Further, more than one non-spherical surfaces may be employed in any one of fourth and fifth lens bands.

When a zoom lens is utilized in order to image on a photo-acceptance unit having more than 3 millions of pixels, each aberration has to be suppressed ~~requires to be suppressed~~ to an extraordinary

small level. However, it is not preferable from a cost point of view also to make the lens construction complex to sufficiently compensate ~~the~~ each aberration.

By constituting each lens band with less than three lenses to be relatively ~~be~~ simple, and utilizing more than one non-spherical surfaces in each of the second and third lens bands and at least any one of the fourth and fifth lens bands, a high imaging performance capable of sufficiently accommodating the photo-acceptance unit can be secured.

As an alternative lens construction capable of obtaining a high performance with a relatively simple construction in the similar manner, a zoom lens may be configured in the following manner.

That is, less than three lenses may constitute the first to third lens bands and fifth lens band. In addition, four lenses may constitute the fourth lens band, and more than one non-spherical surface~~s~~ may be included in each of the second and third lens bands. In addition, more than one non-spherical surface~~s~~ may (whole application) be included in any one of the fourth and fifth lens bands.

In addition, the fifth lens band may include one lens. This may introduce an advantage that movement can be performed with small energy because the fifth lens band weighs relatively light when moved in order to perform compensation of an image surface variance and focussing.

a surface of the non-spherical surface in the optical axis direction at each height of the surface, the reference numeral "C" represents an inverse number of a paraxial curvature radius (i.e., a paraxial curvature) and the reference numeral H represents a height from an optical axis:

$$X = CH^2/\left[1 + \sqrt{(1-(1+k)C^2H^2)}\right] + A_4 \cdot H^4 + A_6 \cdot H^6 + A_8 \cdot H^8 + A_{10} \cdot H^{10}$$

Then, a shape may be defined by giving R (=1/C), K, A_4, A_6, A_8 and A_{10}. Such a "surface number" may be of a number counted starting from the object nearest side surface. A unit of a quantum having a length dimension may be millimeter.

In the first practical example is now described with reference to tables 1A, 1B, 1C, 1D, and 1E, ~~wherein~~ the reference numeral (f) varies from 7.52 to 35.41, that of (F) varies from 2.78 to 4.02, and that of (ω) varies from 32.88 to 7.35 in accordance with zooming.

A plurality of lenses having prescribed properties may be employed as listed on the table 1A (Fig. 50).

Each of the non-spherical surfaces of the fifth, seventh, twelfth, fourteenth, and nineteenth surfaces may be defined by predetermined values listed on the table 1B. Further, a plurality of intervals A, B, C, and D may also be listed on the table 1C. In addition, a plurality of numerical values listed on the table 1D may be assigned to parameters of conditional expressions in this practical example.

Further, both a variable distance and a focal length when magnification from the short to long focal point ends is performed and the fourth lens band comes closest to the third lens band may be listed on the table 1E.

A lens arrangement of the first practical example may be illustrated in Fig. 2, wherein the reference numerals I, II, III, IV and V may represent the first, second, third, fourth and fifth lens bands. In Fig. 2, the reference numeral "S" may represent an aperture diaphragm, and that of FL may represent a variety of lens filters.

These may be similar in subsequent drawings.

The second practical example is now described with reference to tables 2A, 2B, 2C, 2D, and 2E, wherein the reference numeral (f) varies from 7.52 to 35.42, that of (F) varies from 2.68 to 4.02, and that of (ω) varies from 32.96 to 7.32 in accordance with zooming.

A plurality of properties of lenses may be listed in the table ~~1A~~ 2A.

Each of the non-spherical surfaces of the fifth, seventh, twelfth, fourteenth, and nineteenth surfaces in this example may be defined by predetermined values as listed on the table 2B.

In addition, a plurality of intervals A, B, C, and D in this

example may be listed on the table ~~2C~~ 2D.

A plurality of values assigned to parameters of conditional expressions may be listed on the table 2C.

A lens arrangement of the second practical example may be illustrated in Fig. 3.

The third practical example is now described with reference to tables 3A, 3B, ~~and~~ 3C, and 3D wherein the reference numeral (f) varies from 7.52 to 42.48, that of (F) varies from 2.38 to 4.00, and that of (ω) varies from 33.10 to 6.12 in accordance with zooming.

A plurality of lens properties of this example may be listed on the table 3A.

Each of the non-spherical surfaces of the fifth, seventh, twelfth, fourteenth, and nineteenth surfaces may be defined by predetermined values as listed on the table 3B.

A plurality of intervals A, B, C, and in this practical example may be listed on the table 3C. In addition, a plurality of numerical values assigned to parameters of conditional expressions in this practical example may be listed on the table 3D.

Further, a lens arrangement of the third practical example may be illustrated in Fig. 4.

The fourth practical example is now described with reference to tables 4A, 4B, 4C, and 4D, wherein the reference

to fifth lens bands III, IV, and V having positive focal lengths, and the aperture diaphragm "S" disposed in the vicinity of the third lens band III. In addition, when magnification from the short to long focal point ends is performed, the second lens band II may smoothly move toward the third lens band. Simultaneously, the fourth lens band may move from the fifth lens band side toward the long focal point end in the vicinity of the third lens band.

Thus, the fourth lens band may take partial charge of the magnifying function together with the second lens band. Further, an exemplary zoom lens may be designed so that the following inequality may be valid, wherein a distance between the first and second lens bands at the short focal point end is D_{1W}, that between the first and second lens bands at the long focal point end is D_{1T}, that between the third and fourth lens bands at the short focal point end is D_{3W}, and that between the third and fourth lens bands at the long focal point end is D_{3T}:

$$(D_{3W}-D_{3T}) \ / \ (D_{1T}-D_{1W}) > 0.3$$

In addition, the exemplary zoom lens may be for photographic use with the first lens band (I) sides facing an object side. Further, the first exemplary zoom lens may be configured such that the fourth lens band moves from the fifth lens band side toward the long focal point end in the vicinity of the third lens band, and comes closest to the third lens band at a focal

photographing lens 11, the above-described any one set of exemplary zoom lenses may be utilized.

An output of the photo-acceptance unit 15 may be input to a signal processing apparatus 17, and then converted into digital information by the signal processing apparatus 17 controlled by a central processor 21. Specifically, the camera apparatus of Fig. 22 may function to ~~of~~ convert~~ing~~ a photographing image into digital information.

More than three millions of pixels may be used for its photo-acceptance unit 15 so as to receive an image via the photographing lens (i.e., zoom lens) 11.

The image information may receive prescribed image processing in the image processing apparatus 19 under control of the central processor 21 after being converted into the digital information by the signal processing apparatus 17. Such image information may be capable of selectively being displayed on a liquid crystal monitor 23 or stored in a semiconductor memory 27. Otherwise, it can be transferred outside via a communication card or the like 25.

Fig. 22A is a front side view illustrating a mobile information terminal in use. Fig. 22B is a rear side view of the mobile information terminal.

The camera apparatus 10 as the mobile information terminal may have a flat rectangular box shape, and is handled

selectively standing with its liquid crystal monitor 23 being open. Simultaneously, a display of the liquid crystal monitor 23 may face a user (i. e., a photographer side).

In addition, the object lens 11 of the photographic lens (i. e., the zoom lens 11) may face a photographic object.

When a photograph is taken, a switch SW is turned ON, and a photograph mode may then be selected using an operation button 36.

A selected mode may be displayed on a liquid crystal panel 32. Then, while peeping in through an ocular lens of a finder 13 illustrated in Fig. 22B, a photographer may select a zoom ratio through an operation of a zoom lever 38. Focussing may automatically be performed by movement of the fifth lens band.

When a shutter button 30 is depressed, photographing may be performed. The above-described information digitization may subsequently be performed. To display and review the photographed image on the liquid crystal monitor 23, such a request may be selected through the operation button 36.

Since the photographed image is digitized, desired recordation of information may be performed through an operation of the operation button 36 in the semiconductor memory (i.e., memory card) 27 with it being inserted into a dedicated throttle of the camera body.

Otherwise, when the photographed image is to be

transmitted, transmission may be performed through an operation of the operation button 36 with the communication card 25 being inserted into a dedicated throttle of the camera body. In addition, image information transferred from ~~an~~ outside via the communication card 25 can optionally be displayed on the liquid crystal monitor 23.

A plurality of modifications is now described with reference to Figs. 23 to 49, in which a macro mode is applied in a camera. A zoom lens of this invention may include the first lens band I having a positive focal length, the second lens band II having a negative focal length, and the third III, fourth IV, and fifth V lens bands having positive focal lengths arrange from an object side toward an image surface as illustrated in Fig. 23. An aperture diaphragm "S" may also be arranged in the vicinity of the third lens band.

Fig. 23A may illustrate a lens band arrangement of a short focal point end (i.e., a wide-angle end). Fig. 23A ~~23B~~ may also illustrate a lens band arrangement of a telescopic end. Fig. 23B ~~23C~~ may illustrate a lens band arrangement of a macro mode.

The second lens band II may smoothly move toward the third lens band III when magnification from the short to long focal point end (Fig~~s~~. 23A ~~and 23B~~) is performed. Simultaneously, the fourth lens band IV may move from the fifth lens band V side toward the long focal point end in the vicinity of the third

lens band III.

Specifically, the fourth lens band IV may bear part of a magnifying function together with the second lens band II. In addition, there may exist a macro mode that enables focussing at a shorter distance outside a typical photographing region for zooming. In addition, the fifth lens band V may perform focussing by its movement both in the typical photographing region and macro mode.

Such a typical photographing region may represent the entire photographing region in that the focussing is possible at an optional zoom position between the short and long focal point ends including these ends. Simply in other words, it may be a photographing region in that zoom photographing is available.

The macro mode may be a mode that is set outside the typical photographing region and enables lenses to focus at a distance shorter than that of the zoom photographing. A lens band arrangement in the macro mode may be different from that of the lens band for zooming between the short to long focal point ends as illustrated in Fig. ~~23C~~ 23B. Specifically, lens band movement for zooming can not realize the lens band arrangement for the macro mode.

As a zoom lens whose first to fifth lens bands having power allocation such as positive, negative, positive, positive,

and positive, it is known heretofore that the first, third, and fifth lens bands are fixed in case of performing magnification, and the second lens band (variant) is moved so as to perform the magnification. In addition, the fourth lens band (compensating member) is moved so as to compensate a positional variance of an image surface which accompanies the magnification. Thus, since the second lens band substantially bears all of the magnifying function, a moving amount of the second lens band for the magnification is large. In addition, since the first lens band largely steps away from an aperture diaphragm, a light ray valid diameter (i.e., a lens external diameter) of the first lens band ~~results in~~ becomes large when realizing a wide angle.

Then, as mentioned earlier, an exemplary zoom lens may be configured such that the fourth lens band also shears the magnifying function when the magnification is performed.

In addition, the aperture diaphragm may be approximated by the first lens band by minimizing the moving amount of the second lens band.

As a result, the light ray valid diameter of the first lens band may be minimized.

Thus, the focussing in the typical photographing region may be performed by the movement of the fifth lens band. However, to downsize the lens unit, in particular to shorten the entire length, an interval between the fourth and fifth lens bands

should or may be better to be short.

However, there may exist a limit on a moving amount of the fifth lens band when downsized.

Specifically, it may be difficult to extremely shorten the shortest photographing distance (e.g. focussing at 1 to 2cm from a ~~lending~~ leading end of a lens).

In this respect, focussing at a distance shorter than the typical photographing region may be enabled in the macro mode by arranging the second and fourth lens bands in a positional relation different from that arranged when zooming is performed.

Thus, focussing up to a distance (the shortest photographing distance in a macro mode) shorter than the shortest photographing distance for the typical photographing region is required in the macro mode.

Then, the fifth lens band may be selected as a movement objective as similar to a case when focussing in the typical photographing region. As a result, only one lens band may be enough to be driven by a focus signal passed from a distance measurement device or the like (not shown), thereby capable of simplifying a focussing mechanism. Further, a rear lens band illustrated in Fig. 23 may be a variety of filters.

The fourth lens band in a macro mode may preferably be positioned at the fourth lens band at the long focal point end.

Because, when performing focussing by moving the fifth

By setting a focussing range of the macro mode from the shortest of typical photographing region to a short distance under the above-described conditions, a discontinued portion does not appear in available photographing magnifications.

Further, it is preferable that the first lens band of the zoom lens is immobile with regard to an image surface in one embodiment. It is not new itself to fix the first lens band at the times of zooming and focussing. However, the first lens band may be fixed because the first lens band is unnecessary to be moved even when a typical photographing region is switched to a macro mode in the zoom lens according to the present invention. In addition, if the first lens band having heaviest weight is always fixed with regard to the image surface, a number of actuators used for moving a lens band and amount of torque does not need ~~require~~ to be increased. As a result, such a construction may be advantageous in view of cost and power consumption saving.

In addition, the third lens band and the aperture diaphragm may be preferably immobile with regard to the image surface in one example of a zoom lens. Because, a shutter sometimes is arranged at the position of the aperture diaphragm, and movement of the shutter causes undesirable result such as complexity of its mechanism. In addition, the shutter causes vibration when it is driven, and if a configuration enabling

the shutter to move is employed, the vibration may easily travel to another parts of the lens unit, thereby being possible cause of image vibration. Then, ~~the~~ problems such as ~~these mechanism~~ mechanical complexity and image vibration can efficiently be avoided if both of the third lens band and aperture diaphragm are fixed like the zoom lens as stated earlier.

Accordingly, it is preferable that the first and third lens bands as well as the aperture diaphragm may be immobile with regard to the image surface.

In addition, it may be preferable that the following inequality may be valid in an exemplary zoom lens, wherein distances between the first and second lens bands at short and long focal point ends and in a macro mode are L_{1W}, L_{1T}, and L_{1c}, respectively:

$$0.15 < (L_{1c} - L_{1W}) / (L_{1T} - L_{1W}) < 0.40$$

The lower limit of the above-described inequality may be a condition for suppressing a large negative distortion aberration in a macro mode to be small. Thus, if the lower limit is exceeded, a negative distortion aberration that accompanies focussing may be large.

In contrast, if the higher limit is exceeded, focussing toward a sufficiently short distance may be difficult.

In the above-described zoom lens, it may be preferable that the following inequality may be valid, wherein distances

at a long focal point end:

$$(D_{3W}-D_{3T}) \;/\; (D_{1T}-D_{1W}) > 0.3$$

The above-described formula may represent necessity of increasing in a moving amount of the fourth lens band more than a prescribed level when magnification is performed. Specifically, if the parameter $(D_{3W}-D_{3T})/(D_{1T}-D_{1W})$ becomes smaller than the lower limit 0.3, there may exist a probability that the fourth lens band does not sufficiently shear the magnifying function. For example, if supposing a case in which the third lens band is fixed, the element $(D_{3W}-D_{3T})$ may indicate a moving amount of the fourth lens band when magnification from the short to long focal point ends is performed. Similarly, the denominator $(D_{1T}-D_{1W})$ may indicate a moving amount of the second lens band when magnification is performed.

Thus, minimization of the parameter $(D_{3W}-D_{3T})/(D_{1T}-D_{1W})$ becomes small may denote minimization of the element, or enlargement of the denominator. The minimization of the element may denote decrease in a moving amount of the fourth lens band. In contrast, enlargement of the denominator may denote enlargement of a moving amount of the second lens band. Accordingly, a magnifying function to be sheared by the fourth lens band may be minimized in any cases.

Further, along as the parameter $(D_{3W}-D_{3T})/(D_{1T}-D_{1W})$ becomes larger, the rate of shearing magnifying function ~~owned by~~ of the

fourth lens band may become larger. However, if the magnifying function shear rate of the fourth lens band becomes excessively large, the magnifying function shear rate of the second lens band may become smaller, thereby resulting in difficulty in obtaining fair magnification. Accordingly, a limit of the parameter $(D_{3W}-D_{3T})/(D_{1T}-D_{1W})$ may be around 1.0.

In ~~an~~ exemplary zoom lenses, the following inequality may be preferably met by the focal length f_1 of the first lens band, and the composite focal length f_{12T} of the first and second lens bands in order to further downsize and obtain a higher performance:

$$-1.4 < (f_{12T} / f_1) < -1.0$$

Such parameter (f_{12T}/f_1) may denote a magnification rate of the second lens band at the long focal point end. To downsize a lens unit, power of the first lens band is ~~to be~~ strengthened (i.e., to shorten a focal length). In order to design in such manner, it may be preferable that a magnification rate of the second lens band at the long focal point end may be set at less than -1.

However, if the magnification rate of the second lens band at the long focal point end is less than -1.4, since contribution of the fourth lens band to the magnification is weakened and the power of the second lens band should be strengthened, disadvantage may arise in aberration

compensation.

In the zoom lens, when magnification from the short to long focal point ends is performed, the fourth lens band smoothly moves from the fifth lens band side toward the long focal point end in the vicinity of the third lens band. In addition, a positional variance of an image surface which accompanies the magnification performed by the smooth movement of the second and fourth lens bands may be compensated by a movement of the fifth lens band.

In addition, as illustrated in Fig. 23A, the fourth lens band may come closest to the third lens band during its movement from the fifth lens band side toward the long focal point end in the vicinity of the third lens band for magnification at a focal point slightly before the long focal point end. If operat~~ing~~ed ~~them~~ in such a manner, it is possible to enable the fourth lens band to have a function of compensating a positional variance of an image surface accompanying magnification beside a magnifying function.

However, movement during the zooming of the fourth lens band can not be smooth. Thus, ~~if it is designed that~~ a positional variance of the image surface accompanying the magnification is compensated by moving the fifth lens band like the zoom lens, ~~a~~ flexibility for improving a performance may increase and a high performance may readily be obtained. In addition, since

both of the second and fourth lens bands execute smooth movement, a mechanism for moving lens bands can be simplified, and its torque can be lower.

Further, one example of the zoom lens may be configured such that less than three lenses constitute the first to third and the fifth lens bands. Four lens may constitute the fourth lens band.

At least one non-spherical surface may be employed in the second, third, and fifth lens bands, and two or more non-spherical surfaces may be employed in the fourth lens band. When utilizing one example of a zoom lens in order to image on a photo-acceptance unit having more than 3 millions of pixels, it is required for each aberration to extraordinary be suppressed. However, it also is not preferable from a cost point of view to make the lens construction complex in order to sufficiently compensate each aberration.

Like the earlier described zoom lens, by employing an appropriate number of non spherical surfaces in the second to fifth lens band, a high imaging performance capable of sufficiently accommodating a photo-acceptance unit having more than three millions of pixels can be secured.

In addition, the fifth lens band of an exemplary zoom lens may include one lens. This may bring an advantage that movement can be performed with small energy because the fifth

lens band weighs light when moved in order to perform compensation of an image surface variance and focussing.

Further, in one example of the zoom lens, one positive lens may constitute the third lens band, and the aperture diaphragm may be arranged in the object side of the third lens band.

Thus, the third lens band may simply be configured with it being included in a shutter unit.

Further, an exemplary camera apparatus may employ the above-described any one of zoom lenses for photographic use. The camera apparatus may by any one of a conventional silver photographic camera, a digital camera, and a digital video camera having a function of digitizing a photographed image.

The above-described camera apparatus can employ a photo-acceptance unit having more than three millions of pixels in order to receive a light ray of an image via the zoom lens. In addition, the camera apparatus can be utilized in a mobile information terminal.

A plurality of practical examples of a zoom lens is now described with reference to tables 6A, 6B, 6C, and 6D, wherein it is premised that a set of aberrations of each example is sufficiently compensated and thereby capable of accommodating a photo acceptance unit having more than 3 millions of pixels.

The following first to third examples may be types in

A plurality of non-spherical surfaces whose surface numbers have asterisks may be defined by predetermined values listed on the table 7B.

A plurality of intervals A, B, C, and D during the typical photographing and in a macro mode, and conditional expression values are listed on the tables 7C and 7D.

A plurality of properties of the entire lenses of the third practical example may be listed on the table 8A.

A plurality of non-spherical surfaces whose surface numbers have asterisks may be defined by predetermined values listed on the table 8B.

A plurality of intervals A, B, C, and D during the typical photographing and in a macro mode, and conditional expression values may be listed on the tables 8C and 8D.

A plurality of aberration curvatures of the first example at short, middle, and long focal point ends when a photographing distance is infinite may be illustrated from Figs. 4 to 6 one after another. Fig. 7 illustrates a set of aberration curvatures of the first example at the short focal point end when the photographing distance is 0.3 meters. (whole application) Fig. 8 illustrates a set of aberration curvatures at the middle focal length when the photographing distance is 0.4 meter. Fig. 9 illustrates a set of aberration curvatures at the long focal point end when the photographing distance is 0.5 meter. In

addition, Fig. 10 illustrates a set of aberration curvatures when the photographing distance is 0.3 meter in a macro mode. Fig. 11 also illustrates a set of aberration curvatures in a macro mode when the photographing distance is 0.77 meter.

A set of aberration curvatures of the second example at short, middle, and long focal point ends when a photograph distance is infinite may be illustrated from Figs. 12 to 14 one after another.

In addition, Fig. 15 illustrates a set of aberration curvatures of the second example at the short focal point end when the photographing distance is 0.3 meter.

Fig. 16 also illustrates a set of aberration curvatures at the middle focal length when the photographing distance is 0.4 meter. Fig. 17 illustrates a set of aberration curvatures at the long focal point end when the photographing distance is 0.5 meter. Fig. 18 also illustrates a set of aberration curvatures when the photographing distance is 0.3 meter in a macro mode.

Fig. 19 also illustrates a set of aberration curvatures when the photographing distance is 0.77 meter in a macro mode.

A plurality of aberration curvatures of the second example at short, middle, and long focal point ends when a distance is infinite may be illustrated from Figs. 20 to 22 one after another.

image surface.

The following inequality may be satisfied, if distances between the first and second lens bands at short and long focal point ends and in a macro mode are L_{1W}, L_{1T}, and L_{1C}, respectively:

$$0.15 < (L_{1C} - L_{1W}) / (L_{1T} - L_{1W}) < 0.40$$

In addition, the following inequality may also be satisfied, if a plurality of distances between the third and fourth lens bands at short and long focal point ends and in a macro mode are L_{3W}, L_{3T}, and L_{3C}, respectively:

$$0.25 < (L_{3C} - L_{3W}) / (L_{3W} - L_{3T}) < 0.50$$

Further, the following inequality may preferably be satisfied, wherein distances between the first and second lens bands at the short and long focal point ends are D_{1W} and D_{1T}, and those between the third and fourth lens bands at the short and long focal point ends are D_{3W} and D_{3T}:

$$(D_{3W}-D_{3T}) / (D_{1T}-D_{1W}) > 0.3$$

In addition, the following inequality may preferably be satisfied if f_1 and f_{12T} may be focal lengths of the first lens band and a combination focal length of the first and second lens bands at the long focal point end, respectively:

$$-1.4 < (f_{12T} / f_1) < -1.0$$

As illustrated in ~~from~~ Figs. 23 to 25, when magnification from short to long focal point ends is performed, the fourth lens band IV may smoothly move toward a long focal point end in

the vicinity of the third lens band III from the fifth lens band V side. A positional variance of an image surface which is caused by the magnification performed by the smooth movement of the second and fourth lens bands may be compensated by the movement of the fifth lens band.

The first to third and fifth lens bands may be formed by less than three lenses. Four lens may constitute the fourth lens band. More than one non-spherical surfaces may be included in each of the second, third, and fifth lens bands. In addition, more than two non-spherical surfaces may be included in the fourth lens band.

In addition, one lens may constitute the fifth lens band V. The third lens band III may be constituted by a positive lens. The aperture diaphragm "S" may be arranged in the object side of the third lens band III.

Any of the ~~The~~ above-described ~~any one of~~ zoom lenses may be employed in the earlier described camera apparatus.

The mechanisms and processes set forth in the present invention may be implemented using one or more conventional general purpose microprocessors and/or signal processors programmed according to the teachings in the present specification as will be appreciated by those skilled in the relevant arts. Appropriate software coding can readily be prepared by skilled programmers based on the teachings of the

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1. (Amended) A camera apparatus comprising a zoom lens, said zoom lens comprising:

a first lens band having a positive focal length;

a second lens band having a negative focal length;

at least third to fifth lens bands having positive focal lengths; and

an aperture diaphragm located in the vicinity of the third lens band;

wherein, said second lens band smoothly moves toward the third lens~~ed~~ band and said fourth lens band moves from the fifth lens band side toward a long focal point end so as to she~~a~~re a magnifying function together with the second lens band, when magnification is performed from short to long focal point ends.

2. (Amended) A mobile information terminal, comprising a camera apparatus having a zoom lens, said zoom lens comprising:

a first lens band having a positive focal length;

a second lens band having a negative focal length;

at least third to fifth lens bands having positive focal lengths; and

an aperture diaphragm located in the vicinity of the third lens band;

wherein, said second lens band smoothly moves toward the third lens~~ed~~ band and said fourth lens band moves from the fifth lens band side toward a long focal point end, when magnification is performed from short to long focal point ends.

3. (Amended) A zoom lens, comprising:

a first lens band having a positive focal length;

a second lens band having a negative focal length;

at least third to fifth lens bands having positive focal lengths; and

an aperture diaphragm located in the vicinity of the third lens band;

wherein, said second lens band smoothly moves toward the third lens~~d~~ band and said fourth lens band moves from the fifth lens band side toward a long focal point end, when magnification is performed from short to long focal point ends.

4. (Amended) The camera apparatus according to claim 1, wherein a distance (D_{1W}) between the first and second lens bands in the short focal point end arrangement, a distance (D_{1T}) between the first and second lens bands in the long focal point end arrangement, a distance (D_{3W}) between the third and fourth lens bands in the short focal point end arrangement, and a distance (D_{3T}) between the third and fourth lens bands in the long focal point end arrangement substantially meet the following inequality:

$$(D_{3W} - D_{3T}) / (D_{1T} - D_{1W}) > 0.3.$$

5. (Amended) The ~~camera~~ apparatus according to any one of claims 1 and 3, wherein the first lens band faces an object to be photographed.

6. (Amended) The ~~camera~~ apparatus according to any one of claims 1 and 3, wherein said fourth lens band comes closest to the third lens band at a focal length slightly before the long focal point end.

7. (Amended) The ~~camera~~ apparatus according to any one of claims 1 and 3, wherein a variance of an image surface caused by the~~se~~ smooth movements of said second and fourth lens bands is compensated by movement of the fifth lens band in a predetermined direction.

8. (Amended) The ~~camera~~ apparatus according to claim 7, wherein said first lens band is immobile.

9. (Amended) The ~~camera~~ apparatus according to claim 7, wherein said third lens band and aperture diaphragm are immobile.

10. (Amended) The ~~camera~~ apparatus according to claim 7, wherein the fifth lens band performs focussing.

11. (Amended) The ~~camera~~ apparatus according to claim 7, wherein a focal length (f_1) of the first lens band, and a composite focal length (f_{12T}) of the first and second lens bands at the long focal point end substantially meet the following inequality:

$$-1.4 < (f_{12T} / f_1) < -1.0.$$

12. The ~~camera~~ apparatus according to claim 7, wherein a composite focal length (f_{12W}) of the first and second lens bands at the short focal point end, a composite focal length (f_{12T}) of the first and second lens bands at the long focal point end, a focal length (f_T) of the entire lens unit at the long focal point end, and a focal length (f_W) of the entire lens unit at the short focal point end substantially meet the following inequality:

$$0.4 < (f_{12T} / f_{12W}) / (f_T / f_W) < 0.7.$$

13. (Amended) The ~~camera~~ apparatus according to claim 7, wherein each of said lens bands includes less than three lenses, said second and third lens bands include at least one non-spherical surface, and at least one of said fourth and fifth lens band includes more than one non-spherical surfaces.

14. (Amended) The ~~camera~~ apparatus according to claim 7, wherein said first to third and fifth lens bands include less than three lenses, said fourth lens~~d~~ band includes four lenses, each of said second and third lens bands includes at least one non-spherical surface, and at least one of said fourth and fifth lens band includes more than one non-spherical surfaces.

15. (Amended) The ~~camera~~ apparatus according to claim 7, wherein said fifth lens band includes only one lens.

16. (Amended) The ~~camera~~ apparatus according to claim 7, wherein said aperture diaphragm is located at the object side of the third lens band.

17. (Amended) The ~~camera~~ apparatus according to claim 7, further comprising a function of digitizing a photographed image into digital information.

18. (Amended) The ~~camera~~ apparatus according to claim 17, further comprising a photo acceptance unit configured to receive an image from the zoom lens, said photo acceptance unit having almost three million~~s of~~ pixels.

19. (Amended) The ~~camera~~ apparatus claimed in ~~any one of~~ claim~~s 1, and 4 to~~ 15, said zoom lens further comprising a macro mode capable of focussing at a shorter distance than an ordinal photographing region, wherein said focussing is performed by movement of the fifth lens band in a predetermined direction in any one of the ordinal photographing region and the macro mode.

20. (Amended) The ~~camera~~ apparatus according to claim 19, wherein said fourth lens band in the macro mode is substantially close to the fourth lens band in the long focal point end arrangement.

21. (Amended) The ~~camera~~ apparatus according to claim 19, wherein said second lens band in the macro mode is substantially closer to the image surface than when it is in the short focal point end arrangement.

22. (Amended) The ~~camera~~ apparatus according to claim 19, wherein said fourth lens band in the macro mode is close to the fourth lens band in the long focal point end arrangement, and wherein said second lens band in the macro mode is closer to the imaging surface than when it is in the short focal point end arrangement.

23. (Amended) The ~~camera~~ apparatus according to claim 19, wherein the first and third lens bands and the aperture diaphragm are immobile with regard to the image surface.

24. (Amended) The ~~camera~~ apparatus according to claim 19, wherein a distance (L_{1W}) between the first and second lens bands in the short focal point end arrangement, a distance (L_{1T}) between the first and second lens bands in the long focal point end arrangement, a distance (L_{1C}) between the first and second lens bands in the macro mode substantially meet the following inequality:

$$0.15 < (L_{1C} - L_{1W}) / (L_{1T} - L_{1W}) < 0.40.$$

25. (Amended) The ~~camera~~ apparatus according to claim 19, wherein a distance (L_{3W}) between the third and fourth lens bands in the short focal point end arrangement, a distance (L_{3T}) between the third and fourth lens bands in the long focal point end arrangement, a distance (L_{3C}) between the third and fourth lens bands in the macro mode substantially meet the following inequality:

$$0.25 < (L_{3C} - L_{3W}) / (L_{3W} - L_{3T}) < 0.50.$$

26. (Amended) The ~~zoom lens~~ apparatus according to claim 19, wherein a distance (L_{1W}) between the first and second lens bands in the short focal point end arrangement, a distance (L_{1T}) between the first and second lens bands in the long focal point end arrangement, a distance (L_{1C}) between the first and second lens bands in the macro mode substantially meet the following inequality:

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$$0.15 < (L_{1C} - L_{1W}) / (L_{1T} - L_{1W}) < 0.40$$

and wherein a distance (L_{3W}) between the third and fourth lens bands in the short focal point end arrangement, a distance (L_{3T}) between the third and fourth lens bands in the long focal point end, a distance (L_{3C}) between the third and fourth lens bands in the macro mode substantially meet the following inequality:

$$0.25 < (L_{3C} - L_{3W}) / (L_{3W} - L_{3T}) < 0.50.$$

27. (Amended) The ~~camera~~ apparatus according to claim 19, wherein said first to third and fifth lens bands include less than three lenses, said fourth lens~~d~~ band includes four lenses, each of said second, third and fifth lens bands includes at least one non-spherical surface~~s~~, and the fourth lens band includes more than two non-spherical surfaces.

28. (Amended) The ~~camera~~ apparatus according to claim 19, wherein said third lens band includes one lens, and said aperture diaphragm is located at the object side of the third lens band.

29. (Amended) A method for zooming, comprising the steps of:

providing a first lens band having a positive focal length;

providing a second lens band having a negative focal length;

providing at least third to fifth lens bands having positive focal lengths; and

providing an aperture diaphragm located in the vicinity of the third lens band;

smoothly moving said second lens band toward the third lens~~d~~ band;

substantially simultaneously moving said fourth lens band from the fifth lens band side toward a long focal point end so as to sheare a magnifying function together with the second lens band when magnification is performed from short to long focal point ends.

30. (Amended) The method according to claim 29, further comprising the step of bringing said fourth lens band closest to the third lens band at a focal length slightly before the long focal point end in the step of substantially simultaneously moving said fourth lens band.

31. (Amended) The method according to claim 29, further comprising the step of compensating a variance of an image surface caused by the~~se~~ smooth movements of said second and fourth lens bands with movement of the fifth lens band in a predetermined direction.

32. (Amended) The method according to claim 29, further comprising the step of fixing said first lens band when said magnification is performed.

33. (Amended) The method according to claim 29, further comprising the step of fixing said third lens band and aperture diaphragm when said magnification is performed.

34~~3~~. (Amended) The method according to claim 29, further comprising the step of performing focussing with the fifth lens band when said magnification is performed.

35~~4~~. (Amended) The method according to claim 29, further comprising the step of digitizing a photographed image into digital information.

~~35.~~36. (Amended) The method according to claim 29, further comprising

the step of focussing at a shorter distance than an ordinal photographing region by moving the fifth lens band in a predetermined direction in any one of the ordinal photographing region and the macro mode.

37~~6~~. (Amended) The method according to claim 29, further comprising the step of positioning said fourth lens band substantially close to the fourth lens band in the long focal point end arrangement for the macro mode.

38~~7~~. (Amended) The method according to claim 29, further comprising the step of positioning said second lens band substantially closer to the image surface than when it is in the short focal point end arrangement for the macro mode.

39~~8~~. (Amended) The method according to claim 29, further comprising the step of fixing the first and third lens bands and the aperture diaphragm with regard to the image surface.

40~~39~~. (Amended) A camera apparatus comprising zoom means for performing zooming, said zoom means comprising:

first means for deflecting a light, said first means having a positive focal length;

second means for deflecting the light, said second means having a negative focal length;

at least third to fifth means for deflecting the lights, said at least third to fifth means having positive focal lengths; and

means for narrowing the light in the vicinity of the third means;

wherein, said second means smoothly move toward the third means and said fourth means move from the fifth means side toward a long focal point end so as to sh~~e~~are a magnifying function together with the second means when magnification is performed from short to long focal point ends.

~~40.~~41. (Amended) The camera apparatus according to claim 40~~39~~, wherein said fifth means perform focussing during zooming.

42~~1~~. (Amended) A computer program product which stores computer program instructions which when executed by a computer results in a zooming operation in a camera apparatus including a first lens band having a positive focal length, a second lens band having a negative focal length, at least third to fifth lens bands having positive focal lengths, and an aperture diaphragm located in the vicinity of the third lens band, and wherein said zooming operation comprises~~ing~~ the steps of:

smoothly moving said second lens band toward the third lend band; and

substantially simultaneously moving said fourth lens band from the fifth lens band side toward a long focal point end so as to sh~~e~~are a magnifying function together with the second lens band when magnification is performed from short to long focal point ends.

ABSTRACT

A zoom lens includes a first lens band having a positive focal length, a second lens band having a negative focal length, and at least third to fifth lens bands having positive focal lengths. An aperture diaphragm is located in the vicinity of the third lens band. When magnification i.e., zooming is performed from short to long focal point ends, the second lens band smoothly moves toward the third lens~~d~~ band and the fourth lens band simultaneously moves from the fifth lens band side toward a long focal point end so as to sh~~e~~are a magnification function together with the second lens band.